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Costs of Organic Milk Production on U.S. Dairy Farms

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The impact of organic participation on milk production costs is evaluated using data from a nationwide survey of dairy operations. Organic dairies have estimated costs about $5 to $8 per cwt higher than conventional dairies. They also receive an average milk price premium of $6.69 per cwt in 2005. Production costs are estimated to be only $3 to $4 per cwt higher among pasture-based dairies. Results suggest that small conventional dairies may consider converting to the organic approach, but startup organic dairies are not likely unless they can enter at a much larger scale than the industry norm or can utilize pasture as a primary dairy feed source.

Organic milk production is one the fastest-growing segments of organic agriculture in the United States. Between 2000 and 2005 the number of certified organic milk cows on U.S. farms increased by an average of about 25% each year, from 38,000 to more than 86,000 (USDA, Economic Research Service, a). Many of these cows are on relatively small dairy operations that have switched to the organic approach with the expectation of improving farm profitability (Barham, Brock, and Foltz). Despite the growing number of organic dairy operations, there is little information about the relative costs of organic and conventional milk production and the characteristics of those that have chosen the organic approach.[1]

Certified organic milk production systems rely on ecologically based practices that virtually prohibit the use of antibiotics and hormones in the cow herd and the use of synthetic chemicals in dairy feed production. Certified organic milk production systems also attempt to accommodate the animals' natural nutritional and behavioral requirements, for example ensuring that cows have access to pasture (Greene and Kremen). These requirements likely add to production costs and create obstacles to widespread adoption, such as posing additional managerial challenges and risks of shifting to a new way of farming, and significant time and costs associated with the transition to organic production.

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Organic milk producers usually begin as operators of conventional dairies that go through what can be a challenging and costly transition process. Many changes in animal husbandry, land and crop management, sourcing new and different inputs, and initiation of the certification process, among others, are required during transition. For example, current standards of USDA's National Organic Program (NOP) require that the pasture and cropland providing feed for organic dairies must be managed organically for a minimum of thirty-six months before it can be certified. Current standards also require the dairy herd to be fed 100% organic feed and to receive organic health care for twelve months before being certified.[2] Grazing is required for all animals over six months of age. Products and feeds that meet organic standards must be found and organic feeds can be priced at more than double that of conventional feeds. In addition, the approach to management likely needs to be adjusted, as many conventional inputs are no longer available to organic producers (Arnold).

This study utilizes data collected in a national survey of U.S. dairy operations in 2005 for a comparison of milk production costs from conventional and organic dairies. A treatment-effect sample-selection model is used to account for the myriad of factors that influence milk production costs and for the fact that some determinants of both organic participation and production costs, such as the level or type of management, are unobservable. Two equations are estimated simultaneously in the model: (1) a probit equation relating use of the organic approach to farm and operator variables, and (2) an equation relating costs of production to farm and operator variables, including an indicator of whether or not the operation is organic. The empirical model corrects for possible sample selection bias by accounting for the joint distribution of the disturbances.

One objective of the study is to use the model to describe characteristics of organic dairies and examine how these differ from those of conventional dairies. The second objective is to measure the difference in costs between organic and conventional milk production in order to estimate the milk price premiums necessary for organic systems to be competitive with conventional systems. A final objective is to examine whether organic systems are more or less competitive for different segments of the U.S. dairy sector, including dairies in the Northeast and Upper Midwest, pasture-based dairies, and small dairies. This is among the first studies to describe organic milk production in the United States and should be of interest to producers considering the organic approach and to processors trying to supply the expanding organic milk market.

Previous Research

Few studies have attempted to quantify the additional costs and to evaluate the returns from organic milk production. Butler measures the differences between organic and conventional costs of production for dairies in California. The analysis is based on 1999 data from six organic dairies compared to a set of conventional dairies of similar herd sizes chosen from a survey of California milk producers. Results show that organic producers pay much higher prices for feed items, including alfalfa hay and concentrates, but that differences in total feed costs between organic and conventional producers are not statistically significant. Organic producers more often substitute pasture for these higher-priced feed items.

Butler estimates organic milk production costs per cow and per cwt to be about 10% higher than conventional costs. The primary cost differences arise from reduced milk production, slightly higher feed and labor costs, and significantly higher herd replacement and transition costs on organic dairies. Herd replacement costs are significantly higher for organic producers because replacement heifers must be raised organically, or must be purchased from organic heifer breeders. Transition costs are not obtained directly from farmers, but are imputed as the net income foregone during the transition period from selling milk at the conventional price while incurring the higher costs of complying with the 1999 organic requirements in California. Net returns from organic production in 1999 are more than twice those from conventional production on dairies of a similar size. However, compared to the state average, returns to organic production are less than for conventional production.

Dalton et al. (2005) reports the average production costs and returns for 2004 from a sample of thirty organic dairy farms in Vermont and Maine. They report a total cost for organic milk production of $22.58 per cwt, before a deduction for unpaid operator labor and management, which is not significantly different from milk revenues. Thus organic milk production does not generate any return to unpaid labor and management nor does it produce a positive return to farm assets or equity. Even when income from nondairy farming activities is added, the implicit return to unpaid labor and management is only $4.34 per hour. A sensitivity analysis also indicates that an organic milk price of at least $25.00 would be needed in 2004 to break even on returns to assets, and $28.05 is needed to earn a 5% return. These prices are about 9% and 24%, respectively, above the average organic milk price in 2004.

Dalton et al. (2008) follow their prior study with a report about the financial performance of Maine and Vermont organic dairies during three years, 2004 through 2006. Financial performance of the organic dairy farms is reported to improve in each year (2005 and 2006) following the low returns reported for 2004. Average farm size increased during this period (forty-eight to sixty-three cows), and increasing milk prices contributed to higher returns to organic milk production. Compared to a similar sample of small conventional farms, revenues are similar in 2004 and 2005, but 36% higher on organic farms in 2006. In addition, the cost structure of organic and conventional dairies are found to be similar, differing only in areas that contribute 7% or less to the total cost of production.

Barham, Brock, and Foltz describe organic dairy farming in Wisconsin using survey data from organic, management intensive grazing, and conventional operations for 2003 and 2004. Their comparison suggests few differences between organic and other dairies in terms of farm operator characteristics (e.g., education, years farming), but organic operators express greater satisfaction and are more optimistic about their future in the dairy business. Organic dairies are found to be smaller than conventional dairies, but larger than most conventional grazing dairies and often use many of the same technologies as conventional dairies. The authors conclude that organic operations are modernizing more rapidly than other dairies, but with a distinctive approach.

Rotz et al. conduct a simulation analysis to examine the environmental and economic performance of organic grass and organic crop dairies in Pennsylvania. Case studies of four actual organic dairy farms are used to characterize the organic systems. Results show that relative organic and conventional milk prices and levels of milk production determine the profitability of organic systems. The authors conclude that at the relative milk prices for 2006, organic production provides an option for improving the economic viability of dairy operations of a similar scale, but persistently higher organic milk prices are needed to promote the transition to organic systems.

This past research describes organic dairy operations, identifies differences between organic and conventional dairies, and estimates the costs and returns of organic milk production. However, the prior research is limited in the scope and depth of data supporting the analyses. This study addresses some of the limitations of prior studies, taking advantage of a unique nationwide data set of organic and conventional dairies.

Empirical Model

A treatment-effect sample selection model is employed to measure the impact of organic participation on milk production costs (Greene). The model assumes a joint normal distribution between the errors of a participation equation (use of the organic approach) and a treatment equation (measure of production costs). This technique accounts for the possible correlation of unobservable variables with both organic participation and production costs, allowing for an unbiased estimate of the impact of organic production on milk production costs.

Applying the treatment-effect model, use of the organic approach or not can be expressed with the latent variable O_i^* indicating the net benefit from using this approach compared to not using. So that

$$(1) \qquad O_i^* = Z_i\gamma + u_i;\ \text{where } O_i = 1 \text{ if } O_i^* > 0,\ 0 \text{ otherwise}$$

where Z_i is a vector of operator, farm, and regional characteristics. If the latent variable is positive, the variable indicating organic production O_i equals one, and equals zero otherwise. A measure of the impact of organic participation on production costs y_i can be expressed by

$$(2) \qquad y_i = X_i\beta + O_i\delta + \varepsilon_i$$

where X_i is a vector of operator, farm, and regional characteristics.

Equation (2) cannot be estimated directly because use of the organic approach may be determined by unobservable variables, such as management factors, that may also affect production costs. If this is the case, the error terms in equations (1) and (2) will be correlated, leading to a biased estimate of δ. This selection bias can be addressed by assuming a joint normal error distribution with the following form

$$\begin{bmatrix} u \\ \varepsilon \end{bmatrix} \sim N\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} 1 & \rho \\ \rho & \sigma_\varepsilon^2 \end{bmatrix}\right)$$

and by recognizing that the expected costs of using the organic approach are given by

$$E[y_i|O_i = 1] = X_i\beta + \delta + \rho\sigma\varepsilon\lambda_i \tag{3}$$

where λ_i is the inverse Mills ratio. To derive an unbiased estimate of δ, a two-stage procedure can be used starting with a probit estimation of equation (1). In the second stage, estimates of γ are used to compute the inverse Mills ratio, which is included as an additional term in a least-squares estimation of equation (2). This two-stage Heckman procedure is consistent, albeit not efficient. Efficient maximum likelihood parameter estimates can be obtained by maximizing

$$\begin{aligned} L(\gamma, \beta, \sigma, \rho) = & \prod_{O_i=0} \int_{-\infty}^{0} \int_{-\infty}^{\infty} f\left(O_i^*, y_i; \gamma, \beta, \sigma, \rho\right) dy\, dO^* \\ & \times \prod_{O_i=1} \int_{0}^{\infty} \int_{-\infty}^{\infty} f\left(O_i^*, y_i; \gamma, \beta, \sigma, \rho\right) dy\, dO^* \end{aligned}$$

where $f(O_i^*, y_i; \gamma, \beta, \sigma, \rho)$ is the joint normal density function, which is a function of the parameters. In practice, the negative of the log of the likelihood function is minimized using the estimates from the Heckman procedure as starting values.

Once the treatment-effect model is estimated, the difference in costs between organic and conventional dairies is determined by (Greene, p. 788)

$$E\,[y_i\,|O_i = 1] - E\,[y_i\,|O_i = 0] = \delta + \rho\sigma\varepsilon\left[\frac{\phi i}{\Phi i(1 - \Phi i)}\right] \tag{4}$$

where ϕ is the standard normal density function and Φ is the standard normal cumulative distribution function evaluated at variable means.

Data

Data used in this study come from USDA's Agricultural Resource Management Survey (ARMS) administered by the National Agricultural Statistics Service and Economic Research Service. The ARMS data include detailed financial information, such as farm income and expenses, and farm assets and debt, as well as farm and operator characteristics. Specifically, this study used a version of the 2005 ARMS that elicited detailed information about the production practices and costs of milk production. This version targeted dairy operations in twenty-four states that account for more than 90% of national milk production and cover all major production areas.

A subsample targeting organic operations is part of the 2005 ARMS dairy version. Of the total dairy sample of 2,987 farms, 737 samples were targeted at organic operations in nineteen states nationwide as identified from lists provided by the major organic milk processors and certifiers. After accounting for nonresponse and missing data, information on 1,787 farms, including 352 operations producing certified organic milk in sixteen states, are available for the analysis. Among the organic dairies, 325 sell more than 90% of milk production as certified organic and are used in the analysis. Farm survey weights on the ARMS data, proportional to the probability of selection, ensure that the sample expands to represent dairy operations in the twenty-four states and that organic operations represent their appropriate share of the population despite their disproportionate representation in the sample.[3]

Table 1 includes the results of tests of equal means between conventional and organic dairies for ARMS data variables important to this study. Several differences between the groups are clear. On average, organic operations produce less milk per cow and are more likely to be located in the Northeast or Upper Midwest than are conventional operations. Average size of organic operations is much less than conventional operations (82 vs. 156 cows), but this difference is not statistically significant due to the large variation in the estimate for conventional operations.[4] Most operator characteristics are similar for dairies in each group, except that organic farms expect to be in business much longer. Almost half of organic dairy farmers expect to be in business twenty or more years, while half of conventional producers expect to exit in ten years or less.

Organic participation in the treatment-effect model is specified with farm and operator variables generally found to be related to technology adoption (Fernandez-Cornejo et al.) and other farm and local characteristics as independent variables. Farm operator variables include age, education, whether the operator had a major occupation off-farm, and an indicator of the operator's planning horizon. Younger, more educated, and full-time farm operators are expected to be more likely to use the organic approach. An indicator of the operator's planning horizon, whether the operator plans to exit the dairy business in ten years or less, is specified because those with a shorter planning horizon may not want to make investments or take risks associated with organic production. Because of the significant capital investment required for milk production, dairy producers' planning horizon is influenced by the condition of the capital stock and intentions to replace capital items. It is possible that some farm operators revised their planning horizon to be more optimistic after their experience as organic milk producers, or if they made capital investments as part of the organic transition.

Larger operations (number of cows) are expected to be less likely to be organic due to the amount of grazing land required for organic certification and because of the difficulty sourcing the necessary amounts of organic inputs. The proximity and accessibility of grazing land to the dairy operation may also be important because barriers such as highways and streams may limit the amount of available pasture. A quadratic term is specified on the cow number variable. Dairy operations capable of pasture-based feeding are expected to be more likely to use the organic approach because of their relative ease in transitioning to organic production and in maintaining a low-cost organic feed source. More than 60% of organic dairies are classified as pasture-based operations, meaning that at least 50%

Table 1. Test of equality of means on characteristics and costs of U.S. conventional and organic dairy farms, 2005

	Type of Dairy Operation		
Item	**Conventional**	**Organic**	***t*-Stat**
Milk cows (per farm)	156	82	1.20
Milk production (lbs per cow)	18,983	13,601	2.63
Region (percentage of farms/cows)			
Northeast (ME, NY, PA, VT)	26/17	41/26	1.25/2.55
Upper Midwest (MI, MN, WI)	39/25	43/34	0.13/2.36
Corn Belt (IL, IN, IA, MO, OH)	15/10	8/8	1.18/0.71
Southeast (FL, GA, KY, TN, VA)	6/6	0/0	NA
Southwest (AZ, NM, TX)	2/10	0/0	NA
West (CA, ID, OR, WA)	11/32	7/32	0.90/0.03
Farm Operator			
Off-farm occupation (percentage of farms)	2	4	0.24
Education class (percentage of farms)			
Less than high school	18	26	0.75
Completed high school/some college	66	54	1.38
Graduated from college	16	20	0.59
Age (years)	51	49	0.66
Exit dairy business (percentage of farms)			
Ten years or less	51	33	1.99
Twenty or more years	30	47	2.05
Pasture-based feeding (percentage of farms)[a]	18	63	6.42
Technology index[b]	3.72	2.53	3.43
Labor use (hours per cwt)	0.26	0.50	3.32
State average milk price (dollars per cwt)[c]	14.60	14.81	1.74
Farms with milk cows in county[d]	384	255	2.13
Costs and returns (dollars per cwt sold)			
Operating costs	11.22	16.70	6.27
Operating and capital costs	13.93	21.22	5.87
Total economic costs	16.45	27.38	5.29
Milk price	15.19	21.88	20.40

Notes: Statistical significance in test of equality of means is indicated by *t*-statistics greater than 1.96 and 1.65 at the 5 and 10% levels, respectively. NA = not applicable.

Source: 2005 Agricultural Resource Management Survey, USDA National Agricultural Statistics Service and Economic Research Service, unless otherwise indicated.

[a]Farmers report that at least 50% of forage requirements are met from pasture during the grazing season.

[b]The sum of the number of 10 production practices used on the dairy operation, including DHIA program participation; milking 3 times or more daily; use of rbST, artificial insemination, embryo transplants or sexed semen, regular veterinary services, or nutritionist; keeping individual cow records; forward purchasing inputs; and, negotiating price discounts.

[c]State average milk price for the five years including 2001 through 2005 (USDA, National Agricultural Statistics Service).

[d]Farms with milk cows located in the county reported in the 2002 U.S. Agricultural Census.

of seasonal forage (during the grazing months) is from pasture, compared to just 18% of conventional operations.

Location in the Upper Midwest and Northeast is expected to increase the likelihood of being organic because of the history of organic production in these areas and their proximity to significant markets for organic milk. Also, operations located in states with higher average conventional milk prices (five-year average) are not as likely to be organic because the price premium from organic production in these areas may be less. The number of farms with milk cows located in the county is specified to indicate the concentration of milk producers and thus the opportunity to produce organic in an area. Organic processors may locate and expand in areas where there is a high density of milk producers, which lowers hauling and other transactions costs with organic producers.

An indicator of the level of technology used on dairy farms is constructed as the sum of the number of ten production practices used on dairy farms. The ten production practices are: (1) DHIA program participation, (2) milking three times or more daily, (3) use of rbST, (4) use of artificial insemination, (5) use of embryo transplants or sexed semen, (6) use of regular veterinary services, (7) use of a nutritionist, (8) keeping individual cow records, (9) forward purchasing inputs, and (10) negotiating price discounts. Conventional operations score significantly higher on the technology index due to inherent differences in the production systems. For example, some technologies, such as milking three times daily, are not possible on most organic dairies, while others, such as rbST use, is prohibited on organic dairies. The technology index is not specified in the organic participation equation, but is used in the cost of production equations.

Milk Production Costs

Costs of conventional and organic milk production are computed according to standards recommended by the American Agricultural Economics Association and used by USDA in their annual report of commodity costs and returns (USDA, Economic Research Service, b). Costs are computed per cwt of milk sold for three categories: operating costs, operating and capital costs, and total economic costs. Operating costs include costs for feed; veterinary and medical services; bedding and litter; marketing; custom services; fuel, lubrication, and electricity; repairs; hired labor; other costs; and operating interest. Capital costs include the annualized cost of maintaining the capital investment in the dairy operation, and costs for property taxes and insurance. Total economic costs are the sum of operating and capital costs, plus opportunity costs for unpaid labor and land, and allocated costs for general farm overhead items, such as utilities, vehicle registration, and other general business expenses. Total operating costs is an indicator of the relative success of dairy operations in terms of their ability to meet short-term financial obligations. The sum of operating and capital costs provides an indicator of whether dairy operations can replace capital assets as needed and thus stay in business over time. Other costs are primarily opportunity costs of owned resources (land and labor) that may or may not influence production decisions.[5]

Operating cost items, except those for farm raised inputs, are taken directly from survey responses to questions about dairy expenditures for each item. Homegrown harvested and grazed feed costs are computed using market prices for each feed item to estimate the opportunity cost of feed fed to dairy cattle. State average market prices are used to value the harvested feed items fed to dairy cows on conventional dairies (USDA, National Agricultural Statistics Service). Because organic feed prices can be significantly higher than those for conventional feeds, premiums paid for organic feed items are estimated from the ARMS data and added to the state average market prices in order to estimate the opportunity cost of these homegrown organic feeds.[6] Pasture rental rates estimated from the ARMS data are used to approximate the opportunity cost of grazed feed on conventional and organic operations.[7]

Capital costs (economic depreciation and opportunity cost) for milk production are computed using the capital recovery approach (American Agricultural Economics Association, pp. 6–19). Capital recovery is an estimate of the cost of replacing the capital investment for cattle housing, milking facilities, feed and manure storage structures, feed and manure handling equipment, tractors, trucks, and purchased dairy herd replacements used up in the annual production process, plus interest that the remaining capital could have earned in an alternative use. These costs are based on 2005 replacement cost estimates for the dairy assets reported by farmers in the ARMS. Farm expenditures on property taxes and insurance are allocated to the dairy enterprise based an estimate of the enterprise gross margin relative to the whole-farm. Capital costs on organic operations are not computed differently than those for conventional operations.[8]

The largest component of other costs for milk production is for unpaid labor. Unpaid labor is charged using the quantity of labor used for milk production, reported in the survey, times an imputed wage rate. The wage rate reflects the opportunity cost of farm operator labor employed off-farm, estimated from an econometric model of off-farm labor supply and wages (El-Osta and Ahearn), and is used to charge unpaid labor hours worked by operators, partners, spouses, and other family members sixteen years of age or more. Unpaid labor hours worked by individuals less than sixteen years of age are charged the state minimum wage rate. Any differences between organic and conventional dairies are due to the amounts of labor used with each approach, and to a lesser extent, the characteristics of farm operators that influence their opportunity wage (i.e., age, education, location). General farm overhead costs are nonenterprise specific costs allocated to the enterprise based on dairy gross margins, while the land cost is an opportunity cost of the land used for building sites and animal holding areas.

Cost of production per unit is the cost associated with production divided by the number of units produced. In single product enterprises, this cost of production per unit can be compared directly to the price of the product. However, determining the relationship between cost of production and product price is more difficult for joint product enterprises such as dairy operations. Milk is the primary product produced and sold from dairy operations, but secondary revenue sources include cattle sales, cooperative dividends, and the fertilizer value of manure. Costs associated with these secondary sources are not reported separately from those for milk. In order to estimate costs per unit of milk production comparable with conventional and organic milk prices a method is needed to separate the cost of producing milk from those for secondary products.

The method used to estimate unit costs of milk production is to compute an equivalent milk production (i.e., cwt of milk) from all revenue sources and use this as the divisor for production costs (Frank). The formula for calculating the equivalent units of production is the total income from all products divided by the price of the primary product, milk.[9] This provides an estimate of the level milk production equivalent necessary to provide the same total income level without the joint products income. Frank describes this "equivalent production" method as the most meaningful measure for calculating the cost of producing milk because dairy operations have multiple income sources and the resulting unit cost can be compared directly to the milk price.

The three levels of production costs per cwt of milk, operating costs, operating and capital costs, and total economic costs, are specified as dependent variables in the treatment equations regressed on operator and farm characteristics. The number and choice of variables specified in the model is limited due to the sensitively of sample selection models to collinearity (Puhani). Among operator characteristics, younger, more educated, and full-time farmers are expected to have lower costs than other farmers. Production costs are expected to decline with size (number of cows), at a decreasing rate, according to economies of size. Location variables are specified to account for unique regional conditions. The technology index is specified instead of variables for each practice to avoid problems of collinearity. Farms with a higher technology index are expected to have lower costs than other farms. Also, the indicator of pasture-based feeding is included because less feed costs and additional labor costs may be incurred with this practice.

Operating costs on organic dairies average \$5.48 per cwt higher than on conventional dairies (table 1). Higher capital costs raise the difference to \$7.29 for operating and capital costs, and higher labor costs contribute to a \$10.93 difference in total economic costs. Controlling for farm operator, farm, and regional differences among farms, ordinary least squares estimates of production costs regressed on exogenous characteristics and an indicator of organic production indicate a difference of \$4.89 in operating costs, \$5.68 in operating and capital costs, and \$6.86 in total economic costs. As mentioned above, unobserved factors may be correlated with use of the organic approach and production costs, so these least squares estimates may be biased. Addressing this potential selection bias is accomplished with the treatment-effect model.

Results

The empirical model is estimated in Stata (StatCorp) using the maximum likelihood estimator with the treatreg command. ARMS survey weights are specified in the estimation. Robust standard errors from the heteroskedasticity-consistent covariance matrix are reported (White). Model results are based upon analysis of a single year of data (2005) and must be evaluated within this limited context.

Organic Participation

Results of a probit model explaining participation in organic milk production are shown in table 2. These results, used to compute the inverse Mills ratio in the two-stage procedure, are the starting values in the maximum likelihood estimation employed in this study. The model is significant and correctly predicts 85% of dairy farmers' choices. Several variables are statistically significant and have signs consistent with prior expectations.

Table 2. Binomial probit maximum likelihood estimates: Participation in organic milk production on U.S. dairy farms, 2005

Variable Description	Coefficient	Standard Error	Marginal Effect[a]
Constant	−0.8769	1.2131	–
Age (years)	0.0011	0.0044	0.00002
Education class (graduated from college)	0.1951*	0.1114	0.00450
Primary occupation is off-farm	0.0979	0.2710	0.00215
Planning horizon (exit in ten years or less)	−0.5185**	0.1121	−0.01087
Size of dairy (100s of cows)	−0.0572**	0.0261	−0.00112
Size of dairy squared	0.0007**	0.0003	0.00001
Location: Northeast (ME, NY, PA, VT)	0.5188**	0.1504	0.01434
Location: Upper Midwest (MI, MN, WI)	0.4240**	0.1162	0.00956
Pasture-based feeding	0.9193**	0.1001	0.03979
State average milk price (dollars per cwt)	−0.1279	0.0834	−0.00250
Farms with milk cows in county (100s)	0.0290*	0.0161	0.00057
Log likelihood	−116.2736		
Pseudo R^2	0.1520		
Sample size	1,787		

Notes: Dependent variable in the probit equation is whether the farm is an organic dairy operation (0,1). * and ** denote statistical significance at the 10% and 5% levels, respectively. The model correctly predicts use of the organic approach for 237 of the 325 organic producers (73%), and 1,277 of the 1,462 other producers (87%).
[a]The marginal effect is the change in probability for an infinitesimal change in each continuous variable and the discrete change in each dummy variable.

Among operator characteristics, the education and planning horizon variables are statistically significant. The coefficient on the education variable indicates that dairy farmers graduating from college are more likely to be organic producers. Dairy operations planning to exit the industry in the next ten years are less likely to be organic, suggesting that operations with a longer planning horizon are more likely to use the organic approach. More educated dairy farmers with long-term plans to remain in business are probably more willing and able to make the time and human capital investment in the transition to organic production.

Size and location of dairy operations are also important factors influencing organic participation. The likelihood of a being an organic dairy decreases with size (number of milk cows) at a decreasing rate. Larger operations likely have less incentives to go organic because of economies of size in milk production, pasture requirements for organic production that are tied to the number of cows, and because of possible difficulties in sourcing large quantities of organic inputs. Regional variables indicating location in the Northeast or Upper Midwest are associated with a higher probability of organic participation. These are the areas where the organic dairy industry began and have a more developed infrastructure for handling organic milk.

Operations with a pasture-based feeding program are more likely to be organic, possibly because the land base enables them to more easily meet the organic pasture requirement and because pasture is more easily managed organically than are field crops. Statistical significance and the marginal effect are greatest for the pasture-based feeding variable, suggesting that the ability to utilize pasture as a significant source of dairy feed is one of the best predictors of organic participation. The variable indicating county concentration of farms with milk cows has a coefficient that is significant and positively correlated with being organic. This may be the result of organic processors choosing to locate and recruit in areas with a relatively large concentration of producers in order to reduce milk transportation and other transactions costs.

Milk Production Costs

Maximum likelihood estimates of the treatment-effect model for each of the three levels of milk production costs are shown in table 3. The estimated coefficients in the top half of the table correspond to the participation equation and are consistent with results of the probit model. There is no theoretical reason to expect that operator planning horizon, state average milk price, and county number of milk cow farms effect cost of production, as opposed to organic participation, so these are omitted from the estimation. Additional regional dummy variables and the technology index are added to the treatment equations.

Among farm operator characteristics the estimated coefficient on operator age is statistically significant in all the cost models, indicating that older operators have higher costs than those younger (table 3). Operating, operating and capital, and total economic costs all decline as size increases, consistent with economies of size. Costs decline as size increases, at a decreasing rate, as fixed amounts of capital and labor are spread over more units of output. Significant economies of size with respect to capital and labor were expected, but operating costs also decline with size, possibly due to greater feed efficiency or lower prices paid for purchasing feed items in volume on larger farms.

Location differences among farms also influence the costs described by each of the models. The estimated coefficients indicate differences between each region and the reference group, the Northeast region. Statistically significant and negative coefficients on variables for the Upper Midwest and Corn Belt operating, and operating and capital costs indicate that these costs are lower in these regions than in the Northeast. Also, total economic costs are lower in the West and Southwest than in the Northeast. Production costs in the Southeast region are not significantly different from those in the Northeast.

Coefficients on the technology index are statistically significant and negatively correlated with costs in models for operating and capital and total economic costs. This means that farms using more of the ten technologies have lower per unit capital and labor costs, possibly by increasing their productivity. Pasture-based feeding has a negative, but insignificant effect on operating costs. Feed costs might be lower by substituting pasture for other feed items, but lower production from cows on pasture may offset these lower costs. Pasture-based feeding is associated with higher total economic costs due to higher labor requirements with this practice.

The coefficients in table 3 are used in equation (4) to estimate the difference in costs between organic and conventional dairies. The results indicate that operating

Table 3. Treatment-effect model maximum likelihood estimates: Costs of milk production on U.S. dairy farms, 2005

	Operating Costs	Operating and Capital Costs	Total Economic Costs
Variable Description	**Coefficient (Std. Error)**	**Coefficient (Std. Error)**	**Coefficient (Std. Error)**
Participation Equation			
Constant	−1.084	−0.905	−0.909
	(1.361)	(1.252)	(1.224)
Age (years)	0.002	0.001	0.001
	(0.005)	(0.005)	(0.005)
Education class (graduated from college)	0.187	0.193*	0.193*
	(0.116)	(0.114)	(0.112)
Primary occupation is off-farm	0.087	0.096	0.092
	(0.281)	(0.274)	(0.276)
Planning horizon (exit in ten years or less)	−0.535**	−0.522**	−0.523**
	(0.127)	(0.125)	(0.115)
Size of dairy (number of cows)	−0.057**	−0.058**	−0.059**
	(0.026)	(0.027)	(0.029)
Size of dairy squared	0.001**	0.001**	0.001**
	(0.000)	(0.000)	(0.000)
Location: Northeast (ME, NY, PA, VT)	0.514**	0.520**	0.521**
	(0.151)	(0.155)	(0.154)
Location: Upper Midwest (MI, MN, WI)	0.445**	0.429**	0.431**
	(0.147)	(0.142)	(0.125)
Pasture-based feeding	0.927**	0.921**	0.921**
	(0.105)	(0.102)	(0.100)
State average milk price (dollars per cwt)	−0.115	−0.126	−0.126
	(0.091)	(0.085)	(0.084)
Farms with milk cows in county (100s)	0.025	0.028	0.028
	(0.025)	(0.025)	(0.019)
Cost of Production Equation			
Constant	11.393**	16.635**	25.648**
	(1.368)	(1.810)	(3.361)
Age (years)	0.035**	0.066**	0.111**
	(0.017)	(0.022)	(0.041)
Education class (graduated from college)	0.093	0.166	0.208
	(0.421)	(0.531)	(1.089)
Primary occupation is off-farm	1.430	2.117*	4.112
	(1.023)	(1.283)	(3.198)
Size of dairy (number of cows)	−0.091**	−0.309**	−0.758**
	(0.041)	(0.055)	(0.116)
Size of dairy squared	0.001	0.003**	0.009**
	(0.001)	(0.001)	(0.002)
Location: Upper Midwest (MI, MN, WI)	−2.126**	−1.759**	−2.004
	(0.667)	(0.827)	(1.510)

Continued

Table 3. Continued

	Operating Costs	Operating and Capital Costs	Total Economic Costs
Variable Description	Coefficient (Std. Error)	Coefficient (Std. Error)	Coefficient (Std. Error)
Location: Corn Belt (IL, IN, IA,	−2.127**	−1.421*	−1.968
MO, OH)	(0.621)	(0.800)	(1.433)
Location: Southeast (FL, GA,	−0.181	0.994	−0.798
KY, TN, VA)	(0.656)	(0.845)	(1.433)
Location: Southwest	−1.440**	−1.144	−3.266**
(AZ, NM, TX)	(0.621)	(0.821)	(1.642)
Location: West (CA, ID, OR, WA)	−1.068*	−1.306*	−3.721**
	(0.599)	(0.778)	(1.363)
Technology index	0.053	−0.327**	−1.535**
	(0.108)	(0.143)	(0.292)
Pasture-based feeding	−0.052	0.154	3.492*
	(0.675)	(0.849)	(1.833)
Organic dairy	5.372**	5.808**	7.182**
	(1.642)	(1.922)	(1.990)
Sigma	3.993**	5.265**	9.379**
	(0.210)	(0.284)	(0.896)
Rho	−0.053	−0.011	−0.015
	(0.157)	(0.137)	(0.062)
Log likelihood	−149,632	−164,065	−194,179
R^2	0.09	0.11	0.24
Sample size	1,787	1,787	1,787

Notes: Dependent variables in each equation are the operating, operating and capital, and total economic costs per cwt of milk sold, respectively. * and ** denote statistical significance at the 10% and 5% levels, respectively. The R^2 statistic corresponds to the "Cost of Production" equation.

costs for producing organic are $4.78 per cwt higher, operating and capital costs are $5.65 per cwt higher, and total economic costs are $6.79 per cwt higher, after accounting for the influence of other factors on production costs and potential sample selection bias. Coefficients on rho, the correlation between errors in the two equations, are not statistically significant in any model suggesting that selection bias would not have been a problem with least squares estimates.

Segments of the Dairy Sector

Treatment-effect models are also estimated for Northeast and Upper Midwest farms, pasture-based farms, and small farms (less than 150 cows), segments of the dairy sector chosen for this analysis because of their association with choice of organic production. Model estimates for the pasture-based segment of the dairy sector are shown in table 4. Participation equation estimates are similar to those among all farms, except that operator age and education are more important to

Table 4. Treatment-effect model maximum likelihood estimates: Costs of milk production on U.S. pasture-based dairy farms, 2005

	Operating Costs	Operating and Capital Costs	Total Economic Costs
Variable Description	**Coefficient (Std. Error)**	**Coefficient (Std. Error)**	**Coefficient (Std. Error)**
Participation Equation			
Constant	−2.645	−2.098	−2.680
	(2.601)	(2.417)	(2.141)
Age (years)	−0.005	−0.008	−0.017**
	(0.007)	(0.007)	(0.007)
Education class (graduated from college)	0.505**	0.472**	0.513**
	(0.171)	(0.172)	(0.172)
Primary occupation is off-farm	−0.153	−0.102	0.220
	(0.447)	(0.348)	(0.319)
Planning horizon (exit in ten years or less)	−0.736**	−0.630**	−0.476**
	(0.233)	(0.197)	(0.187)
Size of dairy (number of cows)	0.074	0.083	0.097
	(0.094)	(0.094)	(0.111)
Size of dairy squared	−0.002	−0.002	−0.003
	(0.004)	(0.004)	(0.004)
Location: Northeast (ME, NY, PA, VT)	0.622**	0.691**	0.601**
	(0.295)	(0.257)	(0.228)
Location: Upper Midwest (MI, MN, WI)	0.850**	0.813**	0.611*
	(0.278)	(0.268)	(0.327)
State average milk price (dollars per cwt)	0.074	0.051	0.125
	(0.171)	(0.158)	(0.139)
Farms with milk cows in county (100s)	−0.013	−0.028	−0.032**
	(0.021)	(0.017)	(0.015)
Cost of Production Equation			
Constant	7.792**	9.624**	16.124**
	(2.094)	(2.979)	(4.933)
Age (years)	0.092**	0.180**	0.392**
	(0.029)	(0.040)	(0.071)
Education class (graduated from college)	−1.132	−1.383	−3.349*
	(0.725)	(0.976)	(2.021)
Primary occupation is off-farm	−0.394	1.126	−3.230
	(1.167)	(1.744)	(3.971)
Size of dairy (number of cows)	−0.486	−1.612**	−5.765**
	(0.486)	(0.632)	(1.321)
Size of dairy squared	0.012	0.051**	0.209**
	(0.018)	(0.024)	(0.052)
Location: Upper Midwest (MI, MN, WI)	0.081	0.871	3.357
	(1.392)	(1.813)	(3.812)
Location: Corn Belt (IL, IN, IA, MO, OH)	−1.568	−0.816	−0.833
	(1.111)	(1.483)	(2.616)

Continued

Table 4. Continued

Variable Description	Operating Costs Coefficient (Std. Error)	Operating and Capital Costs Coefficient (Std. Error)	Total Economic Costs Coefficient (Std. Error)
Location: Southeast (FL, GA, KY, TN, VA)	−0.258 (1.272)	1.272 (1.574)	−0.516 (2.600)
Location: Southwest (AZ, NM, TX)	0.790 (1.341)	1.596 (2.000)	2.100 (6.011)
Location: West (CA, ID, OR, WA)	0.415 (1.114)	1.874 (1.907)	2.650 (3.901)
Technology index	−0.002 (0.399)	−0.424 (0.472)	−1.895* (0.996)
Organic dairy	10.541** (2.723)	14.323** (2.364)	25.548** (5.260)
Sigma	4.592** (0.721)	5.812** (0.950)	10.250** (2.920)
Rho	−0.596** (0.267)	−0.695** (0.151)	−0.765** (0.145)
Log likelihood	−29,287	−32,110	−38,780
R^2	0.13	0.20	0.32
Sample size	381	381	381

Notes: Pasture-based dairy farms are those on which at least 50% of forage requirements are met from pasture during the grazing season. Dependent variables in each equation are the operating, operating and capital, and total economic costs per cwt of milk sold, respectively. * and ** denote statistical significance at the 10% and 5% levels, respectively. The R^2 statistic corresponds to the "Cost of Production" equation.

use of the organic approach among pasture-based farms, while size of dairy is less important. Operator age and education also affect costs more among the pasture-based dairies than among other dairies, while regional cost differences are not statistically significant.

The estimated difference in production costs between pasture-based organic and conventional farms is much less than among all dairies, at $2.87 per cwt for operating costs, $3.00 per cwt for operating and capital costs, and $3.57 per cwt for total economic costs. Also, the coefficients on rho are statistically significant and negative in the treatment-effect models for pasture-based farms, indicating that selection bias would have been a problem with least squares estimates and the cost differences between organic and conventional pasture-based farms would be overstated without the correction.[10] The correlation of errors between the two equations means that pasture-based dairies using the organic approach have higher costs than other dairies due to unobserved factors, such as the level or type of management, or the quality of inputs used. This is supported by mean production levels that are significantly less among organic pasture-based dairies than for other pasture-based dairies.[11]

Table 5. Estimated additional costs incurred by organic dairy farms in relation to conventional dairy farms in various segments of the U.S. dairy sector, 2005

	Operating Costs	Operating and Capital Costs	Total Economic Costs
		Dollars per cwt Sold	
All Farms			
Producing organic	4.78	5.65	6.79
Transitioning to organic	NA	0.72	0.86
Total additional costs	4.78	6.37	7.65
Northeast and Upper Midwest Farms			
Producing organic	4.51	5.43	6.77
Transitioning to organic	NA	0.69	0.86
Total additional costs	4.51	6.12	7.63
Pasture-Based Farms			
Producing organic	2.87	3.00	3.57
Transitioning to organic	NA	0.38	0.45
Total additional costs	2.87	3.38	4.02
Small Farms (Less than 150 Cows)			
Producing organic	4.67	5.78	7.82
Transitioning to organic	NA	0.73	0.99
Total additional costs	4.67	6.51	8.81

Notes: Transition costs are treated as a capital investment necessary to return the higher organic milk price over the expected life of the operation, and thus are not part of annual operating costs (NA = not applicable). Pasture-based dairy farms are those on which at least 50% of forage requirements are met from pasture during the grazing season.

Results of the models for other segments of the dairy sector show little difference between the higher costs of producing organic among Northeast and Upper Midwest farms, small farms, and all farms. Estimated additional costs for producing organic among all farms and in each segment of the dairy sector are shown in table 5. Sample selection was not an issue in any of the treatment-effect models except among the pasture-based farms.

Transition Costs

The estimated cost differences indicate the additional costs incurred during 2005 by operations producing organic milk relative to conventional operations, but do not include the costs associated with the transition period. Data from the ARMS do not indicate the actual costs incurred during transition, so the estimated cost differences between organic and conventional milk production are used to approximate transition costs. Before an operation is certified to sell organic milk, pasture and cropland for dairy feed must be managed organically for a minimum of thirty-six months and the dairy herd must be fed and managed organically during the last twelve months. During the last twelve months cows may be fed on third-year transitional pasture or crops and certified organic feed. This means that organic operations must undergo three years of higher costs before the higher organic milk prices are received.[12]

Higher costs for three years are considered the investment necessary to return higher milk prices over the expected life of the operation. This investment is determined by the estimated additional costs incurred by organic operations over the three-year transition period. During year 3, when both the land and dairy herd must be managed organically, the total estimated additional costs are charged. During years 1 and 2, when only the land is managed organically, 50% of the estimated additional costs are charged. This corresponds to about half of the feed cost on organic dairies from homegrown supplies which would be managed organically during the full three years. The annualized cost of this investment is computed using the capital recovery approach like the other capital costs on dairy operations (American Agricultural Economics Association, pp. 6–19). The investment is spread over an expected life of twenty years. Nearly half of organic operations report plans to be in business for at least twenty more years.

The estimated transition costs and total additional costs on organic operations are shown in table 5. Transition costs are \$0.72 per cwt for operating and capital costs and \$0.86 for total economic costs. Thus, the total estimated additional costs for producing organic relative to conventional milk among U.S. dairy farms are estimated at \$4.78 per cwt for operating costs, \$6.37 per cwt for operating and capital costs, and \$7.65 per cwt for total economic costs. Among pasture-based dairies the cost differences are estimated at \$2.87 per cwt for operating costs, \$3.38 per cwt for operating and capital costs, and \$4.02 per cwt for total economic costs.

Conclusions

This study takes advantage of unique and detailed data from a survey of U.S. dairy operations for 2005. The data set is unique in that it includes a targeted survey of organic producers sampled at a much higher rate than their occurrence in the population of dairy farms. This allows for a statistical analysis of differences between conventional and organic dairy operations.

Size of operation is found to be a primary factor influencing the likelihood of a dairy operation using the organic approach. Because of significant economies of size in milk production, small farms likely view the organic approach as among the few alternatives to reorganize current resources in a way to improve farm returns and the odds of economic survival. Small-scale production may also be more conducive to sourcing organic inputs, which may be of limited supplies in some areas. Because larger farms have more invested in their current production technology (which typically confines milk cows in large barns and limits access to pasture) and because of economies of size, larger farms likely have less incentive to consider alternatives. Also, larger farms may have more difficultly sourcing sufficient quantities of organic inputs, and transitioning to organic production may require significantly more adjustments on larger farms due to pasture requirements for certification.

Location in the Northeast or Upper Midwest is among the primary factors raising the likelihood of a dairy using the organic approach. These areas have a long history of small dairy operations and thus have the infrastructure available to provide inputs and manage the output from several small operations. In addition, the largest U.S. organic milk cooperative pioneered organic milk production in these regions during the mid 1990s. Proximity to markets with highly affluent consumers also makes these attractive locations for organic milk operations. Access to pasture for dairy feed also has a strong influence on being organic. Operations using pasture-based feeding meet the pasture requirements for organic certification, and organic pasture management is generally easier than organic crop management and may provide less costly feed than purchasing organic dairy feed.

Results of a statistical model to compare conventional and organic milk production costs indicate that average operating costs for organic dairies are $4.79 per cwt higher, and operating and capital costs are $5.66 per cwt higher after accounting for the influence of other factors on production costs and potential sample selection bias. After adding an estimate of the additional costs incurred during transition, these average organic milk production costs are $4.79 and $6.38 per cwt higher, respectively. With an average price premium of $6.69 per cwt for organic milk in 2005, organic milk producers, on average, cover the additional operating and capital costs of organic production in 2005.

Most organic dairies are small operations that utilize primarily unpaid operator and family labor. Returns above operating and capital costs on these small organic operations compare favorably with those of small conventional operations. This suggests that there may be economic incentives for small dairies that have already committed much of the fixed investment in milk production to consider transition to the organic approach. However, additional total economic costs for organic production average nearly $1 per cwt more than the organic milk price premium in 2005. This suggests that prospects for startup organic dairies generating much of a return to unpaid labor and management are limited unless they can enter at a much larger scale of production than the current norm for the organic industry.

The segment of the dairy sector on which organic milk production appears most competitive includes farms able to utilize pasture for a significant portion of dairy feed. Average operating costs for pasture-based organic milk production are estimated to be about $3 per cwt higher, and total economic costs are about $4 per cwt higher than for pasture-based conventional production, significantly less than the average organic milk price premium in 2005. There appears to be incentives for pasture-based dairies to transition to organic production, and possibly for startup organic dairies in situations with pasture suitable to be managed organically for dairy feed.

Results of this study are limited, but do shed light on diary farms using the organic approach and the relative costs and returns of conventional and organic milk production. Most importantly, the suitability of organic production systems varies across dairy farms and organic systems appear to be most conducive to pasture-based situations. However, conclusions derived from the analysis are based on organic and conventional milk and feed price relationships measured in 2005 and could change with adjustments in relative milk prices and in relative prices of conventional and organic inputs.

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Endnotes

[1]The 2007 Census of Agriculture reports 1,617 farms with organic product sales among those classified as dairy cattle and milk production according to the North American Industrial Classification System (NAICS). This is up from 516 farms in 2002.

[2]Dairy farms that transitioned prior to June 2006 were allowed to fed a diet consisting of as much as 20% conventional feed, but must have fed at least 80% organic feed for nine months and then 100% organic feed for three additional months before they were able to sell certified organic milk (Dimitri and Greene).

[3]Of the total samples of 2,987 dairy farms, 1,933 are coded as completed interviews. Of these, 146 are deleted due to missing data for one or more variables. Among the organic milk producers, 367 report organic milk sales during 2005, of which twelve are deleted due to missing data, eighteen are classified as in transition to organic production, and nine are mixed operations, leaving 325 samples usable for comparison with 1,462 conventional dairies. Organic farms comprise 18% of the sample, but only 2% of the weighted number of farms.

[4]The standard error on the estimate of average herd size for conventional operations is more than three times that for organic operations.

[5]Opportunity costs of owned resources may vary significantly among producers and many producers are willing to accept returns to these resources different from assumed charges. Lifestyle preferences and costs of switching occupations, among others, affect producers' perceptions of their opportunity costs.

[6]These premiums reflect the difference in the production costs of organic and conventional feed items, but may also reflect additional transportation costs that could result from a scarcity of organic inputs in some areas. To the extent of which these premiums reflect the scarcity of organic inputs in some areas, the opportunity costs for using these homegrown inputs may be overstated.

[7]A concern is that using the opportunity cost approach to estimate homegrown dairy feed costs might bias the results against farms that produce feed because their feed production costs could be lower than assumed feed prices. This could be problematic because organic and pasture-based operations produce a relatively larger share of their feed than other operations. However, means estimated for whole-farm variable and fixed costs per unit from the ARMS data are not significantly different from per unit enterprise costs estimated with the opportunity cost approach. Enterprise costs for producing milk are useful for this study because they can be directly compared to milk prices.

[8]Butler reports that purchased organic herd replacements are more costly than conventional herd replacements, but the ARMS data do not show a difference in the prices paid for organic and conventional replacement heifers. Any cost differential for homegrown replacement heifers is reflected in the operating costs for organic and conventional operations.

[9]For example, the average gross value of production among U.S. dairy operations in the 2005 ARMS is $500,240 ($447,367 from milk sales, $38,186 from cattle sales, and $14,687 from other income). Dividing by the average 2005 ARMS milk price of $15.23 per cwt yields an equivalent milk production of 32,846 cwt, about 212 cwt per cow.

[10]Ordinary least squares estimates of production costs regressed on exogenous characteristics and an indicator of organic production indicate a difference of $5.25 in operating costs, $5.98 in operating and capital costs, and $7.05 in total economic costs on pasture-based dairies, much higher than those estimates in the treatment-effect models.

[11]Mean production levels are 11,661 pounds per cow on organic pasture-based operations in comparison to 15,269 pounds per cow on other pasture-based operations.

[12]Current NOP transition rules are used to estimate the transition costs even though many of the surveyed farms likely transitioned under the old rules. The current rules are used to reflect the costs faced by conventional farms considering the transition to organic production.

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